Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

The fact that our northern trees and shrubs after they become dormant in the fall require a period of chilling before warm weather will start them into growth again, is a protective adaptation of the highest importance to these plants, for if warmth alone would start them into growth they would begin growing in Indian summer and the stored food that the plant requires for its normal vigorous growth in the following spring would be wasted in a burst of new autumn growth, which would be killed by the first heavy freezes, and would be followed by a winter of weakness and probable death.

Further investigations on the effects of chilling are urged upon those engaged in experimentation bearing on the improvement of horticultural and agricultural practices. It is desirable especially to determine the proper temperatures for the storage of different kinds of seeds, bulbs, cuttings, and grafting wood; proper temperatures for the treatment of plants which are to be forced from dormancy to growth at unusual seasons; and proper temperatures for the storage of nursery stock, so that the nurseryman may have plants in proper condition for shipment on any date he desires.

ON THE NATURE OF THE NEGATIVE CARRIERS PRODUCED IN PURE HYDROGEN AND NITROGEN BY PHOTO-ELECTRONS

BY LEONARD B. LOEB*

RYERSON PHYSICAL LABORATORY, UNIVERSITY OF CHICAGO

Communicated by R. A. Millikan, June 5, 1920

As the result of an investigation of the cause of the abnormalities of the negative ions in air at low pressures (which is to appear shortly), it was found that the results obtained could be explained quite satisfactorily on the basis of a theory proposed by Sir J. J. Thomson.[1] This theory assumes that the electron does not attach to a neutral molecule to generate a negative ion on its first impact, but that on the average it will have a chance of uniting in one out of n impacts with a given type of molecule, where n is a constant which is a characteristic of the type of molecule considered. For air this constant was found to be in the neighborhood of 2.5×10^5. If the oxygen molecule is the molecule to which the negative electron attaches in air—a point of view for which there is considerable evidence—this means that in only one out of 5×10^4 encounters with oxygen molecules does the electron have a chance of attaching itself to a molecule to form a negative ion. It accordingly seemed of interest to see how nitrogen and hydrogen molecules behaved in respect to this theory, and to determine n for them if possible.

The method used for the investigation of this question was to measure the mobilities of the carriers generated as photoelectrons from one plate of a condenser using the Rutherford[2] alternating current method. Light from a quartz mercury arc passed through a quartz window sealed into the side of the brass case housing the condenser and was focussed upon the lower plate of the condenser by means of a quartz lens. The diameter of the plates was 10 cm. and the distance between them 1.65 cm. The upper plate of the condenser was connected to a quadrant electrometer

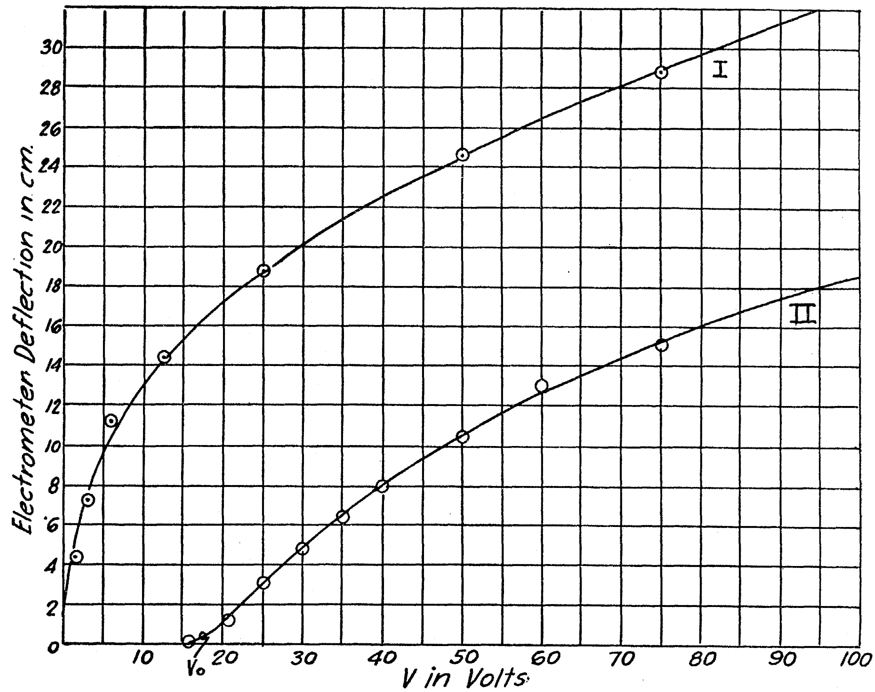

FIG. 1

Air. Press = 95 mm. I—Saturation; II—N = 148

of sensibility 3700 mm. per volt. The lower plate led to a commutator fed by a large battery of dry cells and capable of giving an alternating potential of square wave form of frequency from 15 cycles per second to 750 cycles per second. Connections were so arranged that the positive, or retarding, side of the wave was always about 20% higher than the corresponding negative, or accelerating, side of the wave.

The nitrogen gas which came from a tank of commercial nitrogen was passed over red hot CuO, red hot Cu, over KOH, and $CaCl_2$, over P_2O_5 and finally through a liquid air trap. The commercial hydrogen used was purified in the same way omitting naturally the tube of CuO. The system including the metal housing for the condenser plates was set up so as to eliminate as far as possible all organic vapors such as those coming

from stopcock greases and sealing waxes. The filling of the chamber was accomplished by exhausting to 1.5 cm. pressure and filling slowly with the purified gas six or seven times.

The curves numbered I in figures 1, 3 and 4, give the characteristic photoelectric saturation curves obtained in air at 95 mm. pressure, and in hydrogen and nitrogen at about 750 mm. pressure, when the current to the electrometer plate, under a *constant* accelerating potential is plotted against the potential. When the measurement of the current to the upper

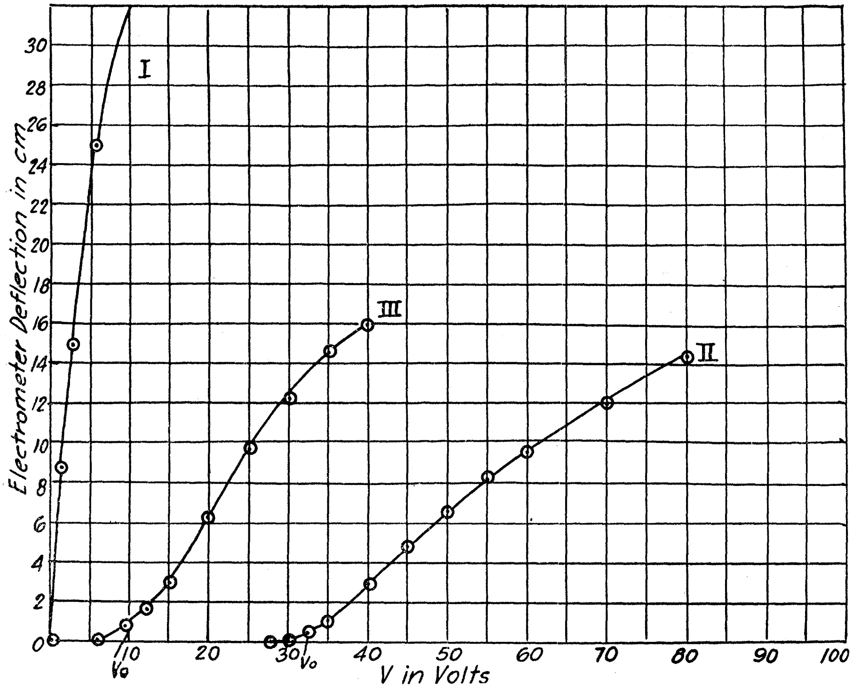

FIG. 2

H_2 743 mm. O_2 12 mm. I—Saturation; II—Press = 293 mm., N = 360; III—Press = 151 mm., N = 364

plate was made using the alternating potentials the results obtained in air, and in hydrogen contaminated with O_2 are entirely different. The current remains nearly 0 until a certain critical voltage V_o is reached, and then rises rapidly eventually approximating a curve of the same shape as the saturation curve, but of half the ordinate. A curve of this type obtained in air at a pressure of 95 mm. using a frequency of alternation of 148 cycles is shown in figure 1, curve II. Figure 2, curves II and III show the results obtained in a mixture of 98.4% hydrogen and 1.6% oxygen at pressures of 293, and 151 mm., respectively. The frequency of the alternating potential was 362 cycles per second. Taking the value of the intercept of these curves with the voltage axis (V_o), one can de-

termine the velocity (u) of the ion in unit field from the equation $u = Nd^2/V_0$ (where d is the distance between the plates and N is the frequency of commutation). By multiplying u by the ratio $p/760$ (where p is the pressure at which the measurement was made) one obtains the mobility constant k of the ion. Now the mobility constant of an ion under normal conditions is of the order of magnitude of 2 cm. per second while that of the electron, though not definitely known, is of the order of magnitude of 200 cm. per second or greater. It is obvious then that by determining the

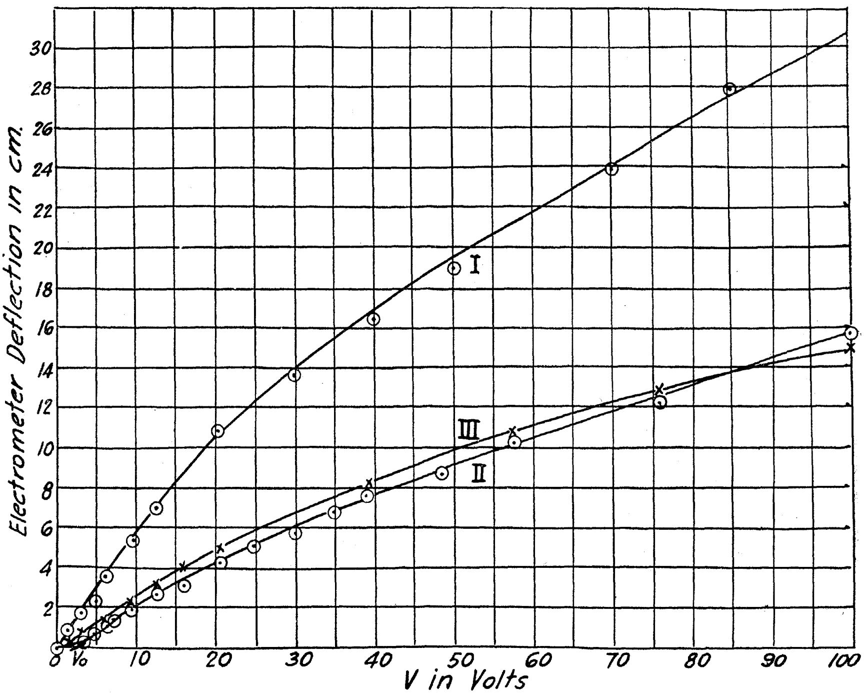

FIG. 3

Pure H_2. Press = 730 mm. I—Saturation; II—N = 712; III—N = 14.5

mobilities of the carriers in the gases the nature of the carriers may be determined.

The value of k obtained from the curves for air is 3.25 cm./sec. The values of k obtained in the mixture of hydrogen and oxygen above are 12.9 and 20.3† cm/sec. respectively, for the two pressures 293 and 151 mm. Since the normal values of k in air and in hydrogen are of the order of 2 cm./sec. and 7.5 cm. /sec. respectively, while those for the electrons in these gases are above 200 and 750 cm./sec., it is to be concluded that the carriers observed above are chiefly ionic in character.

When, however, these measurements were carried out in the carefully purified gases N_2 and H_2 the results were very different. These are illustrated in curves II and III, figure 4 for N_2, using frequencies of 714 and

35.7 cycles per second at a pressure of 753 mm. Curves II and III, figure 3, show the curves obtained in pure H_2 at a pressure of 730 mm. and using frequencies of 712 and 14.5 cycles, respectively.

These curves are practically saturation curves, their intercept with the voltage axis lying very close to the origin and being nearly independent of the frequency of alternation. Their ordinates are, however, but half of those for the corresponding saturation curves. This is to be expected since the time during which the electrometer deflection was measured

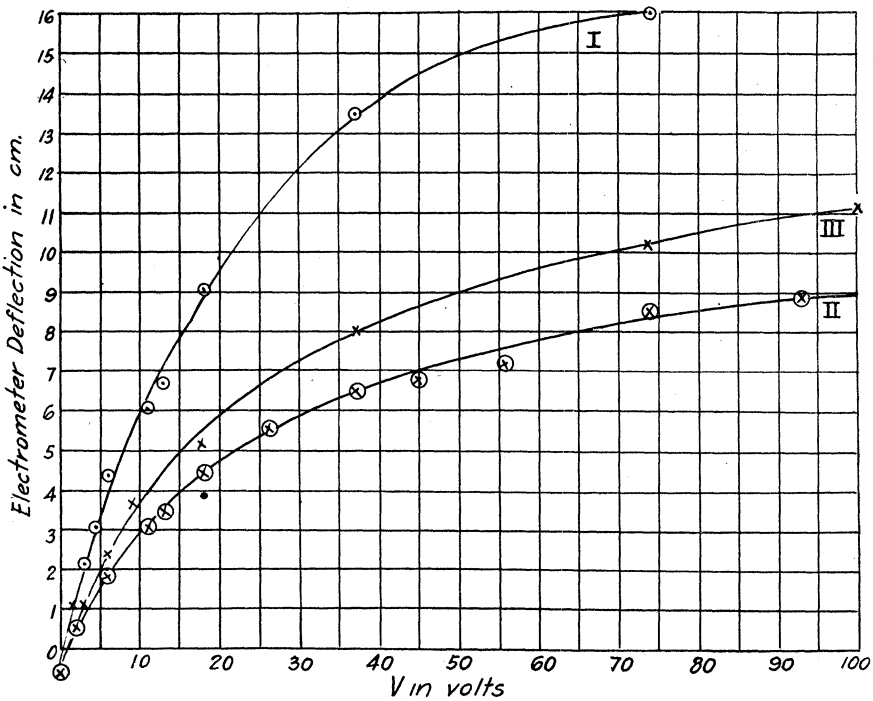

FIG. 4

Pure N_2. Press = 753 mm. I—Saturation; II—N = 714; III—N = 35.7

was the same for the saturation curves as for the curves taken with alternating potentials, while with the alternating potentials the accelerating field was on but half the time. The ordinates of the curves taken with the lower frequencies are in general slightly greater than those with the higher frequencies. This slight difference is probably due to the fact that the contacts at the commutator were slightly better at lower frequencies of alternation. The difference observed in the case of Nitrogen was due to a change in the intensity of the light from the mercury arc whose operating potential changed by two volts between the two determinations. Such a change easily accounts for the difference in the ordinates observed.

It is obvious that the carriers must be entirely electronic for the curves cut the voltage axis at values of V_o so close to 0§ that the values of the

mobility computed therefrom are greater than 750 cm./sec. The conclusion to be drawn is that in pure nitrogen and hydrogen gas the electrons do not attach themselves to the molecules to form ions in any appreciable quantities.

The results obtained in nitrogen are in agreement with those of Franck.[3] The latter used a much more laborious method for the purification of his nitrogen than did the writer. He also used electrons generated by the action of alpha particles on the gas molecules. It is possible that the use of liquid air in the process of purification employed above simplified that process. Both Wellisch[4] and Haines[5] found that in hydrogen even at atmospheric pressure a considerable number of their carriers were electronic in nature. Both of them, however, also found a large proportion of normal negative ions. That they did not obtain the complete absence of ions here obtained is not surprising. For if the purity of their gases had been a little less than that used by the writer, the fact that they generated their ions in an auxiliary chamber where they had considerable opportunity in picking up molecules of the impurity before reaching the measuring field would have given them appreciable numbers of ionic carriers. In his monograph on positive rays J. J. Thomson[6] states that he never observed a single instance of negatively charged nitrogen molecules in his positive ray spectrographs. He did in some cases find molecules of oxygen carrying a negative charge. In a few vary rare instances he found molecules of hydrogen with a negative charge. It is, of course, doubtful whether the results of Thomson with positive rays are in any sense contradictory to the results obtained above for hydrogen. The carriers which Thomson observed were generated in electrical fields of much greater intensity and at much lower pressures than were used in this work. Furthermore Thomson was able to observe carriers whose existence must have been much more transitory than those that the mobility measurements could detect.

According to Bohr's[7] theory the hydrogen molecule permits the incorporation of a third electron into the system to form a stable negative hydrogen ion. It is interesting to note that this does not occur to any noticeable extent under the conditions of the writer's experiments.

In conclusion the writer wishes to thank Professor R. A. Millikan for his very kind advice and criticism.

* NATIONAL RESEARCH FELLOW

† The values of k obtained (p. 438) are somewhat greater than those given for normal ions. These abnormal values of the mobilities are the result of the low pressures used. Their explanation on the basis of the Thomson theory will constitute the body of a later paper.

§ It is impossible to locate the value of V_0 for the curves in Nitrogen. They are too small. The curve in hydrogen obtained with 712 cycles appears to cut the axis near 2 volts. The value of k for the hydrogen carrier deduced from this lies above 900.

However, too much faith cannot be placed on intercepts taken so near the origin, with small deflections.

[1] Thomson, J. J., *London Phil. Mag.*, Sept., 1915.

[2] Rutherford, E., *Proc. Cambridge Phil. Soc.*, **9,** 1898 (401).

[3] Franck, J., *Verh. Deuts. Phys. Ges.*, **12,** 1910 (613).

[4] Wellisch, E. M., *Phil. Mag.*, **34,** 1917 (199); also *New Haven, Amer. J. Sci.*, July, 1917.

[5] Haines, W. B., *Phil. Mag.*, Oct., 1915; also July, 1916.

[6] Thomson, J. J., *Rays of Positive Electricity,* Monographs on Physics, Longmans, Green & Co., 1913.

[7] Bohr, N., *Meddelanden fran k. Vetenskapsakademiens Nobel Institute*, **5,** 1919, No. 28.

SHOCK OR WATER RAM IN PIPE LINES WITH IMPERFECT REFLECTION AT THE DISCHARGE END AND INCLUDING THE EFFECTS OF FRICTION AND NON-UNIFORM CHANGE OF VALVE OPENING

BY W. F. DURAND

LELAND STANFORD JR. UNIVERSITY

Read before the Academy, April 27, 1920

The classic treatment of the problem of shock in pipe conduits, as developed by Joukovsky, Allievi and others, assimilates in effect the condition of the water in the pipe line during the manifestation of the phenomena in question to that of a column of air in a closed organ pipe in longitudinal vibration, the reservoir end of the line corresponding to the mouth end of the pipe and the valve end of the line to the closed end of the pipe. On this basis the theory has been developed in some detail, especially by Allievi.

In the treatment thus developed and in subsequent study of the problem generally, it has been common to omit the following factors, the existence of which must affect the result in actual cases:

(1) The influence of the velocity head $v^2/2g$.

(2) The influence of friction.

(3) The loss of energy through the discharge valve considered as a nozzle.

(4) The influence due to a time rate of valve area closure irregular, or other than uniform.

(5) The influence due to the fact that the valve end of the line is not closed completely so long as the valve is partly open (as in the *operation* of opening or closing). The analogy with the air in a closed organ pipe is, therefore, imperfect and in particular the reflection at this end must, under these conditions, be incomplete rather than complete, as commonly assumed.